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The hexaquark-flavoured antiK-N-N state computed microscopically with a clusterized octoquark

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Abstract

The possible production processes of the antiK-NN are explored. We derive microscopically, with the RGM, the microscopic derivation of the K-N and antiK-N interactions. We discuss the binding or not binding of the different antiK-N and antiK-NN systems. When binding occurs, the respective decay widths are also discussed.

1 production processes

A possible molecular antikaon, nucleon and nucleon three-body system e would be very interesting, both from the exotic hadronic physics perspective and from the few-body nuclear physics perspective.

Notice that the $K^- \bullet N \bullet N$ can be produced with antikaon (K^-) deuteron ($p \bullet n$) scattering. Other exotic tetraquarks, pentaquarks or hexaquarks are also very plausible, but they are all harder to produce experimentally because they would need at least strangeness and charm. The several experiments dedicated to pentaquark searches (where not only the Kaon, but also the antikaon may interact with nuclei), or to antikaon-nuclear binding at RCNP, JLab, KEK, DAFNE and at many other laboratories, are already able to search for the proposed $K^- \bullet N \bullet N$. In particular evidence for $K^- \bullet N \bullet N$ has already been found by the FINUDA collaboration at DAFNE [1]. In Fig. 1 different possible production mechanisms are depicted. They are similar to the $\Lambda(1405)$ production mechanisms, except that the K^- scatters on a deuterium nucleus, not on a hydrogen nucleus. The process in Fig. 1 (a) is

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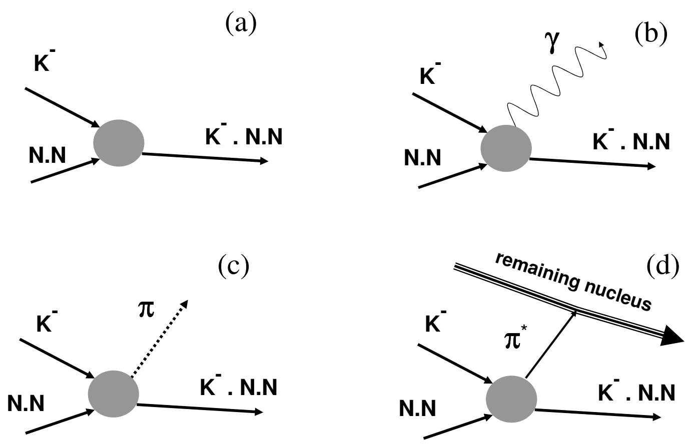

Figure 1: Different $K^- \bullet N \bullet N$ production mechanisms .

only possible if the width of the $K^- \bullet N \bullet N$ is of the order of its binding energy. The process in Fig. 1 (b) is always possible, but is suppressed by the electromagnetic coupling. Processes in Fig. 1 (c) , (d) are dominant.

2 From quarks to the $K \bullet N$

For the $N \bullet N$ interaction we use the precise Nijmegen potentials [2].

We compute the $K^- \bullet N$ interaction microscopically at the quark level. Here we assume a standard Quark Model (QM) Hamiltonian,

$$H = \sum_i T_i + \sum_{i<j\,,\bar{i}<\bar{j}} V_{ij} + \sum_{i\,,\bar{j}} A_{i\bar{j}} \ , \tag{1}$$

where each quark or antiquark has a kinetic energy T_i with a constituent quark mass, and the colour dependent two-body interaction V_{ij} includes the standard QM confining term and a hyperfine term,

$$V_{ij} = \frac{-3}{16} \vec{\lambda}_i \cdot \vec{\lambda}_j \left[V_{conf}(r) + V_{hyp}(r) \vec{S}_i \cdot \vec{S}_j \right] \ . \tag{2}$$

For the purpose of this paper the details of potential (2) are unimportant, we only need to estimate its matrix elements. The hadron spectrum is compatible with,

$$\langle V_{hyp} \rangle \simeq \frac{4}{3} \left(M_\Delta - M_N \right) \tag{3}$$

Moreover we include in the Hamiltonian (1) a quark-antiquark annihilation potential $A_{i\bar{j}}$. Notice that the quark-antiquark annihilation is constrained

when the quark model produces spontaneous chiral symmetry breaking. In the π Salpeter equation, the annihilation potential A cancels most of the kinetic energy and confining potential $2T+V$,

$$\langle A \rangle_{S=0} \simeq \langle 2T+V \rangle_{S=0} \simeq \langle V_{hyp} \rangle \ , \tag{4}$$

leading to a massless pion in the chiral limit. We stress that the QM of eq. (1) not only reproduces the meson and baryon spectra as quark and antiquark bound-states, but it also complies with the PCAC theorems.

We summarize [3–7] the effective potentials computed for the relevant channels,

$$\begin{aligned}
V_{K\bullet N} &= {c_K}^2 \langle V_{hyp} \rangle \tfrac{23}{32} \left(1+\tfrac{20}{23}\vec{\tau}_K \cdot \vec{\tau}_N\right) |\phi^{\alpha}_{000}\rangle \langle \phi^{\alpha}_{000}| \ , \\
V_{\overline{K}\bullet N}(\mathbf{r}) &= -{c_K}^2 \langle V_{hyp} \rangle 2\sqrt{2} \left(1-\tfrac{4}{3}\vec{\tau}_K \cdot \vec{\tau}_N\right) \, e^{-r^2/\alpha^2} \ , \\
V_{\overline{K}\bullet N \leftrightarrow \pi\bullet\Lambda} &= c_\pi c_K \langle V_{hyp} \rangle \tfrac{9}{32} \left(1+\tfrac{4}{3}\vec{\tau}_K \cdot \vec{\tau}_N\right) |\phi^{\alpha}_{000}\rangle \langle \phi^{\alpha}_{000}| \ , \\
V_{\overline{K}\bullet N \leftrightarrow \pi\bullet\Sigma} &= c_\pi c_K \langle V_{hyp} \rangle \tfrac{-5}{8} \left(\tfrac{1+\sqrt{6}}{4} + \tfrac{-3+\sqrt{6}}{3}\vec{\tau}_K \cdot \vec{\tau}_N\right) \\
&\quad\ |\phi^{\alpha}_{000}\rangle \langle \phi^{\alpha}_{000}| \ ,
\end{aligned} \tag{5}$$

where $\vec{\tau}$ are 1/2 of the Pauli isospin matrices for the $I=0$ and $I=1$ cases, and $c_\pi = \sqrt{E_\pi} f_\pi (\sqrt{2\pi}\alpha)^{3/2}/\sqrt{3}$ is a PCAC factor, and $\mathbf{r}$ is the relative coordinate. We calibrate our parameters in the two-body $K \bullet N$ channels, where the diagonalization of the finite difference hamiltonian is straightforward.

3 Results and conclusion

It turns out that in the $K^- \bullet N \bullet N, \ I=1/2, \ S=1$ channel there is no binding [8]. The groundstate has binding in the r_{12} coordinate, but no binding in the r_{123} coordinate. In particular, the r_{12} part of the wavefunction is localized and reproduces the deuteron wavefunction, while the r_{123} part is extended over the whole size of the large box where we quantize the wavefunction. In the limit where the size of the box is infinite, we get a bound deuteron $p \bullet n$ and a free K^-.

In the $S=0$, $K^- \bullet N \bullet N$ three-body system, we have binding because the attraction in the $K^- \bullet N$ sub-systems is increased by a factor of 5/3 when compared with the $S=1$, $K^- \bullet N \bullet N$ three-body system. In particular we find a binding energy $M - m_K - 2m_N \in [-53.0, -14.2]$ MeV, and a decay width $\Gamma \in [13.6, 28.3]$ MeV to the $\pi \bullet \Sigma \bullet N$ and $\pi \bullet \Lambda \bullet N$ channels [8]. The complex pole of this resonance is comparable to the one we get for the $\Lambda(1405)$.

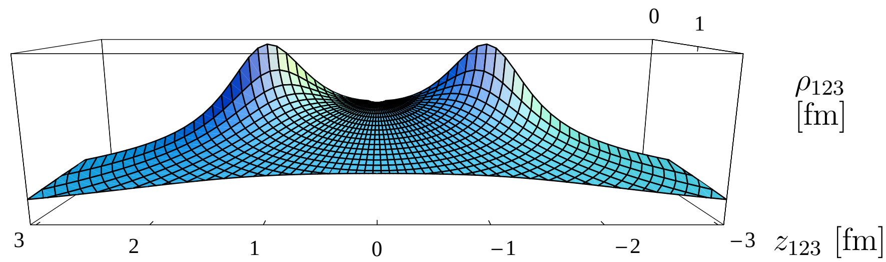

Figure 2: 3d perspective (colour online) of the antikaon wavefunction, assuming two adiabatically frozen nucleons at the distance of $r_{12} = 2.5$ fm.

Acknowledgments

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4 References

References

[1] M. Agnello *et al.* [FINUDA Collaboration], Phys. Rev. Lett. **94** (2005) 212303.

[2] V. G. J. Stoks, R. A. M. Klomp, C. P. F. Terheggen and J. J. de Swart, Phys. Rev. C **49**, 2950 (1994) [arXiv:nucl-th/9406039]; *online codes at* http://nn-online.org .

[3] P. Bicudo and J. E. Ribeiro, Z. Phys. C **38**, 453 (1988).

[4] P. Bicudo, J. E. Ribeiro and J. Rodrigues, Phys. Rev. C **52**, 2144 (1995).

[5] P. Bicudo, Nucl. Phys. A **748**, 537 (2005) [arXiv:hep-ph/0401106].

[6] P. Bicudo, Phys. Rev. D **70**, 111504(R) (2004) [arXiv:hep-ph/0403146].

[7] P. Bicudo, Phys. Rev. D **74**, 036008 (2006) [arXiv:hep-ph/0512041].

[8] P. Bicudo, Phys. Rev. D **76**, 031502 (2007) [arXiv:hep-ph/0701008].